1940

The digestion by calves of milk having varying fat contents and curd tensions

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NOTE TO USERS

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THE DIGESTION BY CALVES OF MILK HAVING VARYING FAT CONTENTS AND CURD TENSIONS

By

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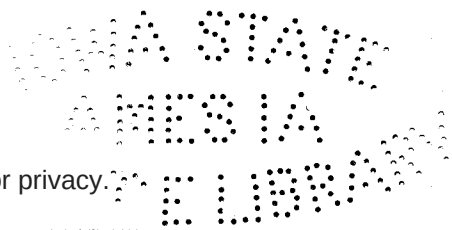
A Thesis Submitted to the Graduate Faculty
for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject Dairy Husbandry



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Iowa State College
1940

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INTRODUCTION

There is a strong feeling among practical dairymen that calves should never get milk containing a high percentage of fat and that rich milk should be diluted with skim milk. The same opinion is expressed by pediatricians through Hill (27) when he says, "Infants have so often had difficulty in digesting milk with a high fat content that doctors have come to associate a high fat milk with digestion troubles in the infant." And today as for many years past, dairymen are having difficulty rearing Guernsey and Jersey calves on their dam's milk. One would ordinarily suspect a difference existing between the milks of the various breeds of dairy cattle.

In a study of the chemical and physical properties of Jersey and Guernsey milk as compared with milk from Ayrshire and Holstein cows, no qualitative chemical differences were found, although a difference in physical property of the curd character has been noted. On the average the milk curd from Ayrshire and Holstein cows is soft and easily broken while with Jersey and Guernsey cows the curd is tough and rubbery.

Information on the variations in the curd character of milk between dairy breeds has prompted research work, the value

of which has found application not only in calf nutrition but in pediatrics as well and has also created a market demand for soft curd milk.

Attention of the public as yet has not been called to extensive trials in which the curd tension of milk and digestion coefficients of milk protein are recorded. In that such little work has been done on this subject, it appears that research work bearing on the effects and interrelationships of varying fat level and curd tension of milk on the coefficients of fat and protein digestion with young calves would be of fundamental importance.

Recent investigations have indicated that soft curd milk leaves the stomach more rapidly than does hard curd milk. This raises questions concerning the digestion by young calves of milks with varying fat levels and curd tensions. In order to answer those questions, this experiment has been designed with the following objectives:

I. To determine how varying curd tensions and fat levels in milk affect the coefficients of fat and protein digestion.

II. To study the effects of varying the curd character and fat content of milk on the titratable acidity, free fatty acids and fatty acids as soap in the feces of young calves.

III. To study the relationship of the fecal reactions such as titratable acidity, free fatty acids and fatty acids as soap to the coefficients of fat and nitrogen digestion.

PART I

The Digestion by Calves of 3 and 6 Per Cent Fat in Milk with Soft and Hard Curd Tensions

Mention was made in the introduction concerning the opinion held by dairy farmers that milk with high fat levels when fed to calves is often detrimental. Morrison (48) has this to say, "A very young animal has only a limited ability to digest and assimilate fat. If it is fed milk containing a greater percentage of fat than is normal for the species, digestive disturbances may therefore result. Even for very young calves, particularly those that are not vigorous, it is best to use milk that is not unduly rich in fat. Thus, in a Jersey or Guernsey herd it is wise to use milk from a low-testing cow for a week or two, or to add warm skim milk or even water to lower the fat percentage." It is true the milk from Jersey and Guernsey cows normally contains a high percentage of fat but it is also characterized by high curd tensions, but when milk is diluted the curd tension as well as the fat content is decreased (16,20). The question then arises, if Jersey and Guernsey calves do better on dilution of their dam's milk, are these results to be ascribed to a lowered fat content or to a lowered curd tension?

A. Review of Literature

1. The composition and physico-chemical characteristics of soft and hard curd milks.

When milk from various cows or after certain treatments is coagulated, a marked variation is noticed in the resulting curd. Some milks form a soft, mushy type of curd, while other milks exhibit an extremely tough and rubbery texture. These differences have been noted by Washburn and Bigelow (68), Washburn and Jones (69), Buckley (8) and Alleman and Schmid (1) all of whom have shown marked differences in the coagula which resulted from the action of rennin on milk. With the exception of Alleman and Schmid (1) none of these workers developed a method of accurately classifying the curd character of milk. Hill (25) in 1923 was the first to advance a commercial method for measuring the curd tension of milk. Hill (25) and later others(46,47,70)showed that as a general rule, soft curd milk is "low test" milk.

The buffer capacity of milk also increases with higher curd tension. Morris et al. (47), Weisberg and co-workers(70) and Doan and Welch (16) have shown that the buffer capacity of soft curd milk is lower than hard curd milk probably due to its lower content of ash, particularly phosphorus and calcium (46,47,70).

2. Endogenous fat metabolism.

It has been demonstrated that the feces of animals on fat-free diets contain ether extract in almost constant quantities. Sperry and Bloor (65) studying the quantitative relations of the fecal lipoids observed in cats and dogs almost as much fatty material in the feces on a fat-free diet as in a fat diet. Sperry and Angevine (64) studied the lipid excretions from dogs on a fat-free diet. The results obtained indicate that relatively large amounts of lipids are excreted into the small intestine. A considerable portion of these excreted lipids is reabsorbed, apparently in the large intestine, though this is not certain. The remainder, together with a relatively small amount of lipids excreted into the colon, probably makes up the endogenous lipid excretions which are found in feces. Holt and co-workers (29) found no constant relation between the per cent of fat in mother's milk and the total fat in the feces of infants. Sperry and Bloor (65) state that there are at least four sources of fat in the feces; intestinal bacteria, desquamated intestinal cells, unabsorbed lipoid residues from food and excretions from the blood either directly or indirectly through the bile and other digestive secretions. Sperry and Angevine (64) conclude from their work that desquamation of intestinal epithelium in all probability is not an important source of the endogenous lipid excretion.

Langworthy and Holmes (36) report the ether extract of the feces from humans contains not only undigested fat but also ether soluble products of metabolism. The ether soluble products of metabolism, 9.89 per cent of the dry matter of feces, were determined on a fat-free ration. The diet in this work contained .69 per cent fat.

Prytz (55) fed skim milk to two calves and found the feces consisted of 2.58 per cent ether extract or a daily excretion of about 1.27 grams.

In our experiment it was necessary to learn the amounts of ether extract normally present in the feces of calves fed skim milk with soft and hard curd tensions in order to make adjustments in the daily fat excreted in the feces of calves when fed 3 and 6 per cent fat milk with soft and hard curd tensions.

3. The digestibility of fat and proteins.

a. Digestion of fat. Much work has been reported concerning the digestibility of fat and proteins. High coefficients of digestion have been observed for both of these nutrients when fed in moderate amounts. In 1915 the United States Department of Agriculture started a series of experiments regarding the digestibility of different kinds of fats. Langworthy and Holmes (36) give from their experiments the digestibility of butterfat in humans as 97 per cent. In 1917 (37) they give

the digestibility of butterfat when given as cream as 96.9 per cent.

Morrison (48) gives the digestibility of butterfat as 97 per cent. Prytz (55) found that the average fat digestion coefficients for butterfat ranged from 93 to 97.

b. The digestion of the milk proteins. Numerous trials have been conducted attempting to determine the digestion coefficients of cow's milk. Among the earliest investigations are those of Camerer (9), Prausnitz (54) and Rubner (61). The coefficients of apparent digestibility of the total nitrogen given by these investigators are 94.3, 91.7, and 93.5 respectively. Each of these investigators reports a three or four day experiment with a human subject given milk as the only food. In each case the milk was fed raw, except in Prausnitz's experiment when it was sterilized by heating for two hours in a steam sterilizer. It is observed that the coefficient for the sterilized milk is slightly lower than those for the raw milk. Rubner (60) later conducted another experiment with a man weighing 70 kilograms. During a two-day period the man consumed 2500 cc. of milk daily, and in a one-day trial he consumed 3000 cc. of milk. Rubner reported the undigested nitrogen of the milk to be 7.02, and 12.91 per cent respectively. Atwater (3) fed raw milk to a man weighing 149 pounds. Trials during which five, eight and nine meals were fed showed that the coefficients of apparent digestibility of

milk protein were 88.1, 90.9 and 95.6 respectively. Bryant (7) reported the results of feeding fresh whole milk containing 5.4 per cent butterfat to an infant weighing 25 pounds. In trials eight and nine days in length the respective values for the digestion coefficients of protein were 93.8 and 95.3.

Raudnitz (57) experimenting with a dog, found that the per cent of undigested nitrogen of raw milk was 12.3, 13.3 and 13.0 for three trials.

Nevens and Shaw (51) working with rats ranging in weight from 102 to 345 grams, determined the apparent coefficients of protein digestion in fresh cow's milk and evaporated milk. Over a period of 47 seven-day trials, the average coefficients of protein digestion were 92.3 ± .17 for fresh whole milk and 88.4 ± .25 for evaporated milk. In a later experiment covering 29 trials, the same authors (51) found the average coefficents of protein digestion were 90.9 ± .20 for whole milk and 87.4 ± .22 for powdered whole milk. In both of these trials similar digestion coefficients were obtained in reversal trials with the same rats. Miyawaki et al. (45),using white rats on four-day trials and preliminary feeding periods of 56 days, found that the apparent coefficients of protein digestion of four brands of dried milk ranged from 86 to 91. To determine whether differences existed in the apparent coefficients of protein digestion of the milk from five major breeds of dairy cattle, Nevens and Shaw (52) obtained the results shown in Table I.

TABLE I

Apparent Coefficients of Protein Digestion of Milk from the Five Major Dairy Breeds Taken on Rats

Breed	Ayrshire	Brown Swiss	Guernsey	Holstein	Jersey
Mean	90.0±.21	92.34±.14	89.7±.36	89.8±.22	89.7±.41
Number of Determinations	30	70	9	48	10

Doane and Price (17) ran a series of three-day digestion trials with calves ranging in age from 14 to 53 days. Six calves fed fresh whole milk digested 94.8 per cent of the proteins in the milk, the means ranging from 89.8 to 97.8. Seven calves fed pasteurized whole milk digested 93.0 per cent of the proteins present, the means ranging from 88.3 to 95.5. When these same investigators used two calves, 41 and 46 days of age, and fed them the same amount of fresh whole milk for three days, the apparent coefficents of protein digestion were 92.8 and 92.5. These same calves when fed pasteurized whole milk, digested 92.1 and 92.0 per cent of the proteins. Skim milk was fed to three calves for three days and the coefficients of protein digestion were found to be 95.2, 94.3 and 94.1. In a later series of experiments the same authors (17) reported that five calves fed fresh whole milk digested 93.5 per cent of the proteins present. Hughes and Cave (35) report the results of a seven-day digestion trial on two calves which had been fed milk alone for several months. They found that the apparent coefficients of protein digestion of milk were 95.7 and 94.8.

c. The effect of fat on protein digestion. There is evidence indicating that fat affects the digestion of proteins. Maignon (41,42,43) experimenting with rats, found that fat was necessary partly for the utilization of protein and partly as a detoxicating agent. Maignon compared albumin-fat and albumin

starch rations and found that the minimum albumin necessary is about one-third less with fat than with starch for the same amount of protein utilization.

Washburn and Jones (69) working with pigs, secured better protein digestion coefficients when the pigs were fed milk moderate in fat content than when milk high in fat was used.

Langworthy and Holmes (37) state that the fats did not materially affect the digestibility of either protein or carbohydrate digestion in their experiments with humans. Morrison (48) states that fat does not increase the digestion of the other constituents of the diet.

Howell (34), commenting on the fat digestion and its effect upon the stomach content, states that fats remain a longer time in the stomach when taken alone, and when combined with other foodstuffs markedly delays their exit through the pylorus.

d. The effect of curd on protein digestion. Little work has been published in which the curd tension and nitrogen digestion coefficients of milk are recorded. Terroine and Spindler (66) employed pigs weighing eight to ten kilograms in their investigations of the effect of pasteurization on the apparent digestibility of the proteins of milk. No difference was found between the protein digestion coefficients of raw and pasteurized milk. However, Magee and Harvey (40) found that the proteins of pasteurized milk were less efficiently utilized by pigs than the proteins of raw milk. Washburn and Jones (69),

in agreement with Magee and Harvey, report that pigs do not use the proteins of evaporated and condensed milks as efficiently as those of raw milk. These results with pigs would almost lead one to believe that the proteins of heated milks are not handled as efficiently as the proteins of raw milk although the curd tension was probably lowered by heating.

Dickey (14) working with seven pairs of rats reported no significant difference between the apparent coefficients of protein digestion of skim milk with a high curd tension and homogenized skim milk with a low curd tension, the respective coefficients were 94.1 and 93.2.

Prytz (55) experimenting with calves found coefficients of 89.81 and 93.43 respectively for the protein digestion of soft and hard curd 2 per cent milk; while the digestion coefficients of the proteins in soft and hard curd 6 per cent milk respectively were 91.79 and 92.25. As the results of a reversal trial with two pairs of Holstein calves, Dickey (14) reported that the coefficients of protein digestion, 91.81 for the hard curd skim milk and 89.81 for the homogenized soft curd skim milk, were not significantly different.

4. The effect of diet on the evacuation of the stomach.

Many investigators are of the opinion that a relationship exists between the emptying time of the stomach and the efficiency of digestion. Brenneman (6) experimenting with humans

found that whiter, harder and longer curds were formed in the stomach with skim milk; but with 13-14 per cent fat in the milk the curds were lightly bound together, easily broken and had the appearance of a coarse cottage cheese. The milk containing 14 per cent fat remained a longer time in the stomach than the skim milk. Hill (26,27,28) describes clinical cases where soft curd milk corrected a variety of digestive disorders in infants fed ordinary mixed cow's milk, either alone or in formulas. Elias (18) was unable to substantiate Hill's claims although he found that in infants' stomachs the coagula from soft curd milk were softer than from certified milk. These coagula were not so soft, however, as those from boiled or evaporated milk. Morris and Richardson (47) concluded that soft curd milk possesses no advantages over the usual formulas for preparing milk for infants.

Hess and co-workers (24) found that modified milks (boiled and acidified) form loose, small curds in the stomachs of puppies, while pasteurized and raw milks form large tough curds.

Doan and Flora (15) fed boiled milk, base exchange treated milk and enzyme treated milk to white rats. On post-mortem examination of the digestion tracts it was found that natural untreated milks are digested about in proportion to their curd tensions. Doan and co-workers (16) fed young rats hard and

soft curd milks, reconstituted evaporated milk, and buttermilk. At various intervals following the feeding period individuals were chloroformed and post-mortem examinations of the digestive tract immediately made. It was found that soft curd milk forms a large curd lump in the stomach of the rat but that it is softer and looser than that formed by hard curd milk. Evaporated milk forms a loose, fine-particle curd substance while buttermilk fails to form a curd structure but appears as a pasty mass.

Dickey (14) working with calves, found that hard curd milk required an average of 9 hours and 29 minutes to be liquefied in the abomasum while homogenized skim milk required 6 hours and 46 minutes for digestion. Milk treated with enzymes of the hog pancreas tend to have a low curd tension and according to Conquest et al. (12) when fed to calves, passed out of the stomach more rapidly than normal pasteurized milk. Doan and co-workers (16) fed twin male Holstein calves for 46 days. One was fed milk with an average curd tension of 25 grams and the other calf was fed milk with a curd tension of 85 grams. The calves were slaughtered, the digestion tracts opened immediately and the contents separated and weighed. The data from these two calves indicate that soft curd milk is more rapidly eliminated from the stomach of calves and digested than is hard curd milk. Espe and Cannon (19) studying the physiological effect of 3 and 6 per cent fat levels in milk on the rate of

evacuation from the abomasums of calves, found that curd from milk containing 3 and 6 per cent fat tends to leave the abomasum more rapidly than skim milk. They concluded that gastric secretion and motility apparently were not inhibited by milk containing 3 or 6 per cent fat.

Mortenson, Espe, and Cannon (49) observed that heat treated milks were evacuated from the abomasum of calves more quickly than untreated milk. While on the other hand McSwiney and Spurrel (39), Quigley, Zettelman and Ivy (56) and Roberts (58) have found that by increasing the amount of fat in the meal the emptying time of the stomach is delayed.

5. The effect of diet on the reaction of the feces.

The role of diet in causing fluctuations in the reaction of the solid excretion has been the subject of considerable debate. Our work was undertaken hoping that the findings of these studies might help to clarify this relationship of diet to feces in calves.

We made no effort to learn the origin or cause of differences in titratable acidity, free fatty acids and fatty acids as soap in the feces of calves, but simply studied the daily fluctuations of these reactions in the feces of calves when they were fed milk with varying fat content and curd tension. We also wanted to learn if these fecal reactions were correlated with the coefficients of fat and protein digestion.

The results of the work done in this field are highly variable. Howe and Hawk (33) were among the first to use the electrometric method and make actual measurements of the hydrogen ion concentration of feces. The reactions were always found to be alkaline, varying with different subjects and conditions from pH 7.01 to 8.77.

Nelson and Williams (50) devised a method for measuring the hydrogen ion concentration of feces colorimetrically. In their experiments with humans the material was usually acid. In only one case out of 30 did the pH rise above 7.0. As a rule the pH varied between 5.0 and 6.0 and in some few cases it went below 5.0.

They (50) also found that pronounced variations in diet such as changes from low to high protein intake or fasting were accompanied by no consistent fluctuations in the fecal reaction. The drinking of large quantities of water, however, appeared to produce a slight increase in alkalinity.

Grayzel and Miller (23) found that diets high in fat, protein or carbohydrate caused no notable changes in intestinal reaction in dogs. Slight acidity prevailed throughout the tract.

McClendon and co-workers (38) in connection with their investigation state: "The mineral content of the food does not seem to be a factor in determining the pH since the acidity of the intestinal contents is greater on a diet of carrots that

yield a basic ash than on a diet of oats that yield an acid ash."

Robinson (59) attributes changes in fecal reaction chiefly to biological causes and claims that it can be regulated indirectly by dietary control of the intestinal flora. In regard to the direct influence of diet he states that with good digestion a mixed diet gives a reaction fluctuating about the neutral point; a preponderance of carbohydrates or fat produces an acid stool while with a heavy meat intake the reaction, though variable, tends to be alkaline; and mother's milk causes the excretion of acid feces while cow's milk changes the reaction to the alkaline side.

Schlossmann (62) does not attribute the change in fecal reaction to mother's milk or cow's milk as such, but to the change in the protein-fat ratio. A ratio of 1 part protein to 3 or more of fat (as in mother's milk) gives an acid stool while a decrease in the protein-fat ratio of 1 to 1 or less gives an alkaline stool.

The relationship between the fat content of the diet and the fatty acids as soap in the feces has not been conclusively demonstrated. Spreey and bloor (65) have shown that the food fat is different from the feces fat in composition, the influence of fat in the diet is, however, shown by the increased excretion of the solid fatty acids on a diet high in solid acids and a similar increase of liquid fatty acid in the excre-

tion when the food contains large amounts of liquid fatty acids.

Bosworth (5) studying infant stools found that calcium soaps precipitated in the intestine may carry down with them by occlusion neutral fat and free fatty acids. When calcium is given in excess it is eliminated in the feces as calcium soaps and calcium phosphates. The calcium soaps in the stool were proportional to the amount of calcium in the food. When calcium-free milk was fed, fat absorption was almost complete.

Holt, Courtney and Fales (31) found no relationship between the excretion of calcium in the stools and total fat excretion but that a relationship did exist between calcium in stools and fat as soap.

Holt et al.(31) found that with a higher total intake of fat the fatty acids as soap were increased in the feces of infants.

Howe (32) working with young calves found that the fat content of feces increases from birth to approximately the third day, after which it decreases and assumes an approximately normal level. During the first three days there is present in the feces a greater proportion of fatty acids in the form of soap, indicating a lack of absorption on the part of the young animal.

Investigating the influence of fat and curd tension upon the digestibility of milk, Prytz (55) found that by increasing

the fat percentage in milk there was an increase in the fecal content of fatty acids present as soap.

Holt, Courtney and Fales (29) found with infants fed on cow's milk that constipation produced very little variation from the normal in the percentage of dry weight of total fat or of soaps. However, in cases of diarrhea the variation in fat content was much greater than when the elimination of the feces was normal. The fatty acids as soap declined from 72.8 per cent of the total fat in normal stools to 8.8 per cent in severe diarrheal stools at the same time the free fatty acids which ordinarily constituted about 17 per cent of the total fat of normal stools was frequently increased in diarrheal stools to over 20 per cent.

Powweather (22) in studying the composition of the fat in the feces of eighty hospital patients suffering from no digestive disorders found that any specimen in which the neutral fat exceeds 12 per cent of the total dry matter or 60 per cent of the total fat should be suspected of showing evidence of deficient fat splitting. Any specimen in which the total split fat (free fatty acids and combined fatty acids) exceeds 20 per cent of the dry matter or 75 per cent of the total fat should be suspected of deficient fat absorption. In diarrheal stools there was evidence of deficient fat splitting and fat absorption.

Waide (67) working with calves at this station found that the free fatty acids averaged 26.27 per cent of the total fat in the feces of calves receiving 4 per cent milk and 20.94 per cent of the total fat in the feces of the calves fed skim milk. Prytz(55) found that increasing the percentage of fat in the diet of calves increased the percentage of free fatty acids present in the feces.

B. Experimental

1. The experimental design.*

If dairymen are going to continue feeding milk to young calves it is important for them to know what type of milk (curd tension and fat content) ought to be fed. Such a knowledge would eliminate waste from our present feeding practices.

In setting up this experiment a design of the factorial type was used in order to test statistically the significance of fat and nitrogen digestion coefficients obtained when the fat content and curd tension of the milk fed young calves varied. The data were analyzed by analysis of variance and tests of significance applied to the results (63).

The factors involved in the analysis of variance are as follows:

Source of Variation	Degree of Freedom
Total	125
Curds	1
Fats	2
Curd x Fat Interaction	2
Experimental Error	12
Sampling Error	108

The term significance is used in this thesis to mean the probability of an event occurring by chance five times or less

* The design of this experiment was developed with the help of Professor Gertrude Cox of the Statistical Laboratory of Iowa State College.

out of a hundred trials, while the term highly significant means the probability is 1 per cent or less.

The design used in the experiment follows:

Soft Curd			Hard Curd		
Calf Number	Butter fat	Days 1 ------- 7	Calf Number	Butter fat	Days 1 ----- 7
1868			1915		
1871	No-fat		1919	No-fat	
1872			1920		
1893			1929		
1894	3%		1930	3%	
1906			1931		
1909			1934		
1911	6%		1935	6%	
1926			1936		

2. Method of procedure.

With the exception of five animals purchased from private breeders the calves used in this experiment were selected from the Iowa State College dairy herd. Male Holstein calves of approximately 12 days of age were used in these trials. Additional information concerning these calves are recorded in Table II.

Since all of the calves were not available when the experiment began regimentation of the calves into lots on a weight basis was not possible. The calves were fitted into the various groups of the experiment as they became available.

TABLE II.

Data Regarding Trials with Calves Fed Milk Containing Different Percentages of Fat and Curd Tensions

Milk Fed	Calf Number	Weight* lbs.	Age* days	Date Trial Started	Date Trial Was Completed	Remarks
Soft Curd						
			(No Fat)			
	1868	114	12	12- 9-39	12-16-39	
	1871	92	12	12-12-39	12-19-39	
	1872	80	12	12-14-39	12-21-39	
			(3% Fat)			
	1893	85	12	2- 9-40	2-16-40	Scouring on Feb. 12, 13 and 14.
	1894	106	12	2-11-40	2-18-40	Scouring on Feb. 12 and 14.
	1906	115	14	3-22-40	3-29-40	
			(6% Fat)			
	1909	85	12	4- 2-40	4- 9-40	
	1911	88	15	4- 6-40	4-13-40	
	1926	99	12	6-16-40	6-23-40	
Hard Curd						
			(No Fat)			
	1915	98	12	4-27-40	5- 4-40	
	1919	92	12	4-28-40	5- 5-40	
	1920**	96	13	7- 3-40	7-10-40	
			(3% Fat)			
	1929	96	12	6-24-40	7- 1-40	
	1930**	115	12	6-25-40	7- 2-40	
	1931**	112	12	6-25-40	7- 2-40	
			(6% Fat)			
	1934	93	12	7-14-40	7-21-40	
	1935**	126	12	7-17-40	7-24-40	
	1936**	108	12	7-22-40	7-29-40	

* Weight and age at beginning of trial.
**Purchased from private breeders.

The metabolism trials with the Iowa State College dairy calves were carried on in a small room in the North barn at the Iowa State College dairy farm. The room was well ventilated and the temperature kept fairly uniform. While the trials with the calves purchased from private breeders were carried on at the Poultry farm in a small calf shed. These latter trials were conducted during the late spring and early summer so that the weather was warm and pleasant.

a. Handling of experimental animals.

(1). Care and feeding of the calves. The calves were left for three days with their dams, before being placed in a stall where they were fed milk approximating in character that milk which they were to receive during the trial. At eight days of age the calves were muzzled. From then on the milk which they received was identical in character with the trial diet. In addition to muzzling of the calves they were put in stanchions so as to acquaint them with tying as in the metabolism crates. This proved successful because the calves when placed in the crates at approximately 12 days of age were very quiet and not disposed to nervousness from strange surroundings.

Sufficient milk was fed each calf so as to maintain the weight from the beginning to the end of the experiment. Daily consumption of milk is recorded by Table III. Whenever a calf tended to scour its milk allowance was cut down. While on

TABLE III.

Daily Milk Consumption by Calves
(Seven Day Period)

Milk Fed	Calf Number	Days 1	2	3	4	5	6	7	Total
		gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
Soft Curd									
					(No Fat)				
	1868	3888	3888	3852	3888	872	3836	3780	24004
	1871	3226	3246	1602	2748	2718	2688	2688	18916
	1872	2898	2762	2394	2364	1804	2334	2304	16860
					(3% Fat)				
	1893	2808	2718	2746	1383	1356	1549	1545	14105
	1894	3196	1488	1574	1758	1762	2515	3030	15323
	1906	2965	3021	3354	4008	3972	3972	3972	25264
					(6% Fat)				
	1909	2580	2565	3009	3045	3063	3063	3126	20451
	1911	3132	3117	3132	3186	3168	3150	3186	22071
	1926	3183	3183	3183	3183	3183	3240	3240	22395
Hard Curd									
					(No Fat)				
	1915	3921	3528	3024	3135	4029	3429	4449	25515
	1919	3222	3255	2463	2760	3036	3054	3276	21066
	1920*	3859	4086	4086	4086	4086	4086	4086	28375
					(3% Fat)				
	1929	3400	3400	3400	3400	3400	3400	3400	23800
	1930*	4900	4900	4900	4900	4900	4900	4900	34300
	1931*	4900	4900	4900	4900	4900	4900	4900	34300
					(6% Fat)				
	1934	2724	3178	2724	3632	3632	3405	3178	22473
	1935*	4313	4313	3632	3859	4086	4086	4086	28375
	1936*	4086	4086	4086	4086	4086	4086	4086	28602

*Purchased from private breeders.

trial the calves were given a teaspoonful of concentrated cod liver oil every other day.

(2). Kinds of milk used. The soft and hard curd milks used in this experiment were selected from special groups of cows in the College herd. Each kind of milk was standardized to 3 and 6 per cent fat levels respectively through first separating the fat from the milk and then adding the necessary cream to the skim milk. Sufficient amounts of the prepared milks were drawn from the milk in the cooling room, steam heated to approximately 37°C three times daily and fed to the calves. The amounts of milk consumed were recorded as well as the amounts refused. The character of the curd in the milk given each calf was determined at the beginning and end of each trial.

(3) The metabolism trials. Each metabolism trial was run for seven days. The trials were begun at a specified time and continued for 24 hours. This simply meant the calf would be fed for a 24-hour period, the feces for that period collected and the daily digestion coefficients calculated. This procedure was repeated for seven consecutive days. The metabolism trials were begun at 6:00 o'clock in the morning and completed at the same time seven days later. The feces were collected daily in a fecal pouch. The fecal pouch was constructed of rubberized cloth and a heavy piece of wire. The pouch was fitted to the

contour of the calf's rear end. The wire was turned into an angle just forward of the scrotum and continued around the thighs to a point just forward of the thurls where it was turned directly over the rump and the two ends fastened. The rubberized cloth was riveted to the wire. A small opening was made in the cloth permitting the calf's tail to hang outside of the pouch. The pouch had a baglike effect so as to catch the feces. The pouch was fastened to the calf by means of a strap attached to the angle of the wire just forward of the scrotum and to the point at the thurls.

The metabolism crates were so constructed as to provide ample room for each calf to lie down and get up again but short enough so that the calf could not lay on the fecal pounch.

During the trials the milk was fed from buckets three times daily. When each batch of milk was standardized a sample was taken for nitrogen analysis, weighed into Kjeldahl flasks and covered with concentrated sulfuric acid.

Each morning while on trial the weight and rectal temperature of each calf was taken and recorded. These are shown in Tables I V and V. Also a daily record was kept of the room temperature.

The fecal pouch was emptied each morning. The contents of the pouch were removed as carefully and completely as possible with a rubber paddle and transferred to a pre-weighed pan which was re-weighed. The difference between the two weighings representing the amount of feces for the preceeding 24-hour period.

TABLE IV.

Daily Weights of Experimental Calves
(Seven Day Trial Period)

Milk Fed	Calf Number	Days 1	2	3	4	5	6	7
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Soft Curd								
				(No Fat)				
	1868	114	113	112	112	112	111	114
	1871	92	91	91	94	94	93	93
	1872	80	78	79	78	79	81	81
				(3% Fat)				
	1893	85	82	83	83	82	84	84
	1894	106	105	103	103	104	106	105
	1906	115	117	115	113	114	114	114
				(6% Fat)				
	1909	85	86	85	86	87	87	87
	1911	88	89	89	91	90	90	90
	1926	99	98	100	101	99	100	101
Hard Curd								
				(No Fat)				
	1915	98	96	98	97	95	97	96
	1919	92	93	92	92	93	92	94
	1920*	96	94	93	94	94	93	95
				(3% Fat)				
	1929	96	94	95	95	97	96	96
	1930*	115	115	115	115	116	115	117
	1931*	112	114	114	113	114	114	116
				(6% Fat)				
	1934	93	94	94	96	94	94	95
	1935*	126	126	127	127	129	128	129
	1936*	108	106	105	106	109	106	107

*Purchased from private breeders.

TABLE V.

Daily Rectal Temperatures of Calves
(Seven Day Period)

Milk Fed	Calf Number	Days 1	2	3	4	5	6	7
Soft Curd								
					(No Fat)			
	1868	102.5	102.0	102.3	105.0	104.3	102.3	101.9
	1871	100.8	100.9	101.6	99.8	100.5	100.0	100.2
	1872	101.0	99.8	102.0	101.0	102.0	101.0	100.0
					(3% Fat)			
	1893	101.6	102.8	101.8	102.0	101.4	102.0	102.2
	1894	100.8	101.6	101.8	102.4	102.0	100.6	102.4
	1906	100.0	100.0	102.0	102.0	102.2	101.8	101.8
					(6% Fat)			
	1909	102.0	101.8	102.8	102.0	102.0	102.4	102.8
	1911	102.6	101.8	102.2	101.6	102.4	102.6	103.0
	1926	101.0	101.2	101.0	101.5	101.2	101.5	100.8
Hard Curd								
					(No Fat)			
	1915	101.0	101.2	100.0	101.0	101.0	101.3	101.2
	1919	100.4	101.4	101.6	101.2	101.5	101.0	101.5
	1920*	101.0	101.5	101.2	101.5	100.8	101.5	102.0
					(3% Fat)			
	1929	101.2	101.3	103.1	101.5	101.8	100.8	101.3
	1930*	101.0	101.2	102.6	101.2	101.5	101.3	101.5
	1931*	102.2	101.8	101.8	100.8	101.0	102.2	101.6
					(6% Fat)			
	1934	101.5	102.0	101.0	101.2	101.8	102.8	102.0
	1935*	101.2	101.5	102.0	102.4	102.8	102.6	101.8
	1936*	101.5	100.8	101.5	102.2	101.2	100.8	101.6

*Purchased from private breeders.

The daily fecal excretions are recorded in Table VI. The feces were then thoroughly mixed, transferred to a pint glass jar and tightly closed. The feces were taken to the chemistry laboratory when they were analyzed for titratable acidity, dry matter, fat (ether extract), free fatty acids, fatty acids present as soap and nitrogen. The daily moisture contents of the feces are recorded in Table VII. Any irregularities observed with the calves during the trials were recorded in Table II.

3. Analytical methods.

The methods of analyses used in this experiment for the most part are the same as those used by Prytz (55), and are presented here.

Milk: The selected milk was analyzed for its fat content by the Babcock method. After standardization it was again tested. The curd tension of the milk was determined by a modification of the Hill method (27) approved by the Curd Tension Committee of the American Dairy Science Association (13). The average curd tensions of the milks used in this experiment were as follows:

SOFT CURD: 38 grams

HARD CURD: 168 grams

Milk nitrogen was determined in triplicate samples by the Kjeldahl, Arnold, and Gunning Method (2).

Feces: In order to determine the quantitative acidity of the feces it was necessary to know the titratable acidity. This was accomplished by dissolving approximately a one gram sample in acetone and then titrating with tenth normal potassium

TABLE VI.

Daily Fecal Excretions by Experimental Calves
(Seven Day Period)

Milk Fed	Calf Number	Days 1	2	3	4	5	6	7	Total
		gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
Soft Curd									
					(No Fat)				
	1868	23	48	203	36	54	230	62	656
	1871	172	170	120	130	75	21	83	771
	1872	56	145	100	70	70	85	80	606
					(3% Fat)				
	1893	70	200	768	461	701	711	193	3104
	1894	296	156	251	161	154	61	166	1245
	1906	68	146	73	85	153	136	89	660
					(6% Fat)				
	1909	138	147	41	46	24	111	36	543
	1911	86	73	96	86	94	120	51	606
	1926	201	71	54	84	40	46	46	542
Hard Curd									
					(No Fat)				
	1915	26	46	41	17	31	30	16	207
	1919	122	171	48	68	65	161	75	710
	1920*	120	102	39	43	28	63	57	452
					(3% Fat)				
	1929	122	40	16	27	24	20	44	293
	1930*	24	66	38	114	139	78	40	499
	1931*	125	120	80	102	110	71	117	725
					(6% Fat)				
	1934	70	68	108	94	100	164	59	663
	1935*	86	58	54	91	63	49	143	544
	1936*	58	125	147	56	101	119	63	669

*Purchased from private breeders.

TABLE VII.

Moisture Content of Feces
(Seven Day Period)

Milk Fed	Calf Number	Days 1	2	3	4	5	6	7	Average
		%	%	%	%	%	%	%	%
Soft Curd					(No Fat)				
	1868	73.8	74.2	78.9	90.1	79.0	83.8	83.6	80.5
	1871	84.2	84.3	86.2	81.9	79.8	82.0	82.4	82.9
	1872	79.9	78.4	76.3	76.8	77.7	82.2	81.6	78.9
					(3% Fat)				
	1893	78.1	78.3	93.8	93.2	95.0	94.8	88.5	88.8
	1894	91.2	86.8	89.7	90.0	85.0	82.0	73.7	85.5
	1906	81.4	78.4	75.2	79.6	76.4	75.8	76.5	77.6
					(6% Fat)				
	1909	58.5	87.7	80.8	74.8	75.3	59.3	76.7	73.3
	1911	77.5	75.8	75.5	74.4	78.0	76.3	75.0	76.1
	1926	74.6	72.6	73.1	75.1	75.0	74.1	74.8	74.2
Hard Curd					(No Fat)				
	1915	77.1	78.6	80.9	75.7	71.7	79.7	78.2	77.4
	1919	77.6	86.2	85.3	83.1	84.9	81.0	74.8	82.0
	1920*	78.5	76.3	77.0	75.8	76.1	75.3	76.8	76.5
					(3% Fat)				
	1929	76.6	78.4	78.9	78.7	78.9	80.7	82.0	79.2
	1930*	65.9	73.7	72.8	75.0	78.2	78.3	77.8	74.5
	1931*	74.3	75.2	77.6	77.6	78.9	84.2	82.9	78.7
					(6% Fat)				
	1934	73.2	73.5	76.5	78.2	79.5	63.3	80.0	74.7
	1935*	81.7	84.0	78.6	77.4	79.8	78.9	78.2	78.4
	1936*	71.8	83.0	83.9	86.9	80.0	84.4	80.4	81.5

*Purchased from private breeders.

hydroxide, using methyl red as an indicator (62).

Triplicate nitrogen determinations were made by the Kjeldahl, Arnold, and Gunning method (2) on the fresh samples of feces.

The dry matter was determined by drying the fresh feces in an electric oven at about 95 - 100°C. until constant weight had been obtained.

The crude fat (ether extract) was obtained by extracting the dried samples of feces with ether for 36 hours in a Soxhlet apparatus. The ether was distilled from the mixture of ether and fat and the residue dried on a hot plate.

The dried residue was dissolved in benzene and titrated while hot with tenth normal alcoholic sodium hydrate in order to determine the free fatty acids. Phenolphthalein was used as an indicator.

The dry fat-free feces were then acidified with dilute hydrochloric acid (1-3) and gently heated in order to convert the soaps of the feces into free fatty acids. The soap as free fatty acids was then determined by the method of Folin and Wentworth (21).

TABLE VIII.

Daily Fat Excretion in Feces of Calves
(Seven Day Period)

Milk Fed	Calf Number	Days 1	2	3	4	5	6	7	Total
		gms.	gms.	gms.	gms.	gms.	gms.	gms.	gms.
Soft Curd									
					(No Fat)				
	1868	.36	.63	2.49	.88	.44	2.23	1.72	8.85
	1871	1.98	1.55	1.18	1.71	1.18	.30	.97	8.87
	1872	.60	1.75	1.70	1.14	1.07	.55	.42	7.24
					(3% Fat)				
	1893	1.43	3.89	7.88	4.07	2.19	2.54	3.37	25.37
	1894	13.44	3.54	9.13	4.60	7.13	4.52	2.41	44.17
	1906	4.67	4.34	2.17	1.31	1.62	1.40	2.74	18.25
					(6% Fat)				
	1909	6.61	1.97	1.50	3.36	1.10	7.16	1.56	23.26
	1911	2.18	2.88	4.45	4.95	4.67	6.53	2.10	27.76
	1926	14.36	3.58	3.73	5.15	2.62	3.38	3.60	36.42
Hard Curd									
					(No Fat)				
	1915	.37	1.08	.56	.30	.78	.57	.29	3.95
	1919	1.73	1.06	.26	.43	.37	1.25	.74	5.84
	1920*	.74	.59	.21	.25	.16	.37	.31	2.63
					(3% Fat)				
	1929	7.90	1.36	.32	.65	.65	.48	1.63	12.99
	1930*	1.36	2.58	2.74	4.51	5.33	3.34	1.34	21.20
	1931*	4.47	3.26	2.27	2.93	1.87	1.12	1.52	17.44
					(6% Fat)				
	1934	6.50	6.59	5.65	3.57	5.92	11.77	3.42	44.33
	1935*	1.70	.99	1.06	2.37	1.62	1.43	3.74	12.91
	1936*	2.65	2.13	2.42	1.04	2.59	2.75	1.98	15.59

*Purchased from private breeders.

C. Results

1. The skim milk experiment.

Six calves were used in the skim milk experiment, three calves on soft and three calves on hard curd skim milk. Each day of the seven that the calves were on trial ether extract determinations of the feces were made. The results of these determinations are shown in Table VIII. Throughout the literature ether extract and fat have been used interchangeably, we shall continue that practice in this thesis. The average daily amounts of fat in the feces of each calf on the soft and hard curd skim milk are presented in Table IX.

TABLE IX.

Average Daily Amounts of Fat in the Feces Taken for Seven Days from Six Calves Fed Soft and Hard Curd Skim Milk

Milk	Fat			
	gms.	gms.	gms.	Average
Soft curd	1.25	1.27	1.03	1.18
Hard curd	.56	.83	.38	.59

The daily amounts of feces fat from the calves on the skim milk diet (Table VIII) were statistically analyzed and the results are presented in Table X. This was done to de-

termine if skim milk varying in curd character and fed to calves had any influence on the amount of fat excretions in the feces. As previously mentioned we also wanted to obtain a fat factor in order to make adjustments for feces fat when calves were fed soft and hard curd milk containing 3 and 6 per cent fat.

TABLE X.

Variance Analysis of the Daily Amounts of Fat in the Feces of Calves Fed Soft and Hard Curd Skim Milk

Source of variation	Degress of freedom	Mean square
Total	41	
Curd	1	3.69
Experiment error	4	1.17
Sampling error	36	.20

According to the results of the variance analysis the curd character of fat-free milk when fed to calves does not influence the amounts of fat in the feces.

TABLE XI.

Fat Digestion Coefficients Taken on Twelve Calves Fed Milk Varying in Fat Content and Curd Tension

Milk Fed	Calf Number	Days 1	2	3	4	5	6	7	Average
Soft Curd					(3% Fat)				
	1893	98.30	95.23	90.43	90.19	96.42	94.53	92.73	93.72
	1894	95.13	90.28	95.40	97.52	96.74	98.14	96.98	95.77
	1906	94.89	97.51	96.93	96.34	98.02	96.21	97.98	96.63
					(6% Fat)				
	1909	95.73	98.72	99.17	98.16	99.40	96.10	99.17	98.06
	1911	98.84	98.46	97.42	97.41	97.70	96.54	98.90	97.90
	1926	92.48	98.12	98.05	97.30	98.63	98.23	98.11	97.27
Hard Curd					(3% Fat)				
	1929	92.25	98.67	99.69	99.36	99.36	98.55	98.40	98.04
	1930*	99.07	98.24	98.14	96.93	96.37	97.73	99.09	97.94
	1931*	96.96	97.78	98.39	98.01	98.73	99.24	98.96	98.30
					(6% Fat)				
	1934	94.70	95.33	95.39	97.82	96.38	92.32	97.58	95.64
	1935*	99.12	99.49	99.35	98.64	99.12	99.22	97.96	98.98
	1936*	98.56	98.84	98.68	99.43	98.59	98.50	98.92	98.79

*Purchased from private breeders.

TABLE XII.

Fat Digestion Coefficients and Other Data on Fat Intake and Outgo
With Calves Fed Milk Varying in Fat Content
and Curd Tension

Milk Fed	Calf Number	Age	Date Trial Started	Date Trial Was Completed	Intake		Outgo		Fat Apparently Retained	True Fat Retention*	Coefficient of Digestibility
		days			Milk gms.	Fat gms.	Feces gms.	Fat gms.	gms.	gms.	
Soft Curd											
						(3% Fat)					
	1893	12	2- 9-40	2-16-40	14105	423.2	3104	31.7	404.1	397.8	94.0
	1894	12	2-11-40	2-18-40	15323	459.7	1145	24.5	447.8	441.5	96.2
	1906	14	3-22-40	3-29-40	25264	757.9	1236	51.1	719.4	713.1	96.6
						(6% Fat)					
	1909	12	4- 2-40	4- 9-40	20451	1227.1	543	29.9	1210.1	1203.8	98.1
	1911	15	4- 6-40	4-13-40	22071	1324.3	606	34.1	1302.8	1296.5	97.9
	1926	12	6-16-40	6-23-40	22395	1336.9	542	42.7	1306.8	1300.5	97.3
Hard Curd											
						(3% Fat)					
	1929	12	6-24-40	7- 1-40	23800	714.0	293	20.3	706.3	700.0	98.0
	1930**	12	6-25-40	7- 2-40	34300	1029.0	499	27.5	1014.1	1007.0	97.9
	1931**	12	6-25-40	7- 2-40	34300	1029.0	725	23.7	1017.9	1011.6	98.3
						(6% Fat)					
	1934	12	7-14-40	7-21-40	22473	1007.7	663	49.7	970.6	964.3	95.7
	1935**	12	7-17-40	7-24-40	28375	1276.9	544	19.2	1270.3	1264.0	98.9
	1936**	12	7-22-40	7-29-40	28602	1337.1	669	21.9	1327.8	1321.5	98.8

* A correction factor, .9 gram, has been subtracted from the daily fecal fat, so as to correct for the naturally occurring fat (ether extract) in feces.

**Purchased from private breeders.

2. The fat digestion trial.

The fat digestion coefficients determined on 12 calves fed soft and hard curd milk containing 3 and 6 per cent fat are presented in Table XI and also summarized in Table XII. The fat digestion coefficients were calculated, using the feed fat (Table III) and feces fat (Table VIII), in the following manner:

$$\text{coefficient of fat digestion} = \frac{\text{feed fat} - (\text{feces fat} - .9)}{\text{feed fat}} \times 100.$$

The factor, .9, obtained from the skim milk trial, was subtracted from each daily amount of feces fat, thereby correcting for endogenous fat metabolism. The averages of the fat digestion coefficients of Table XI are presented in the following table:

TABLE XIII.

The Average of Seven Fat Digestion Coefficients Taken on Each of 12 Calves Fed Soft and Hard Curd Milk Containing 3 and 6 Per Cent Fat

Milk	Fat		
	3%	6%	Average
Soft curd	96.63	97.74	97.18
Hard curd	98.09	97.80	97.94
	97.36	97.77	

In order to test whether the digestion coefficients of fat were affected by the curd tension and fat level at which

the milk was fed to calves, the data (Table XI) were statistically analyzed. The results of this analysis are shown in Table XIV.

TABLE XIV.

Variance Analysis of Fat Digestion Coefficients Obtained with Calves Fed Soft and Hard Curd Milk Containing 3 and 6 Per Cent Fat

Source of variance	Degrees of freedom	Mean square
Total	69	
Curd	1	3.9
Fat	1	.1
Curd x fat interaction	1	7.1
Experimental error	6	8.7
Sampling error	60	2.1

The results of this analysis show that when soft and hard curd milk containing 3 and 6 per cent fat was fed to calves no significant differences were obtained between the fat digestion coefficients. This simply means that fat was as efficiently digested by calves fed soft or hard milk containing 3 or 6 per cent fat.

TABLE XV.

Nitrogen Digestion Coefficients Obtained With Calves Fed Milk Varying in Fat Content and Curd Tension

Milk Fed	Calf Number	Days 1	2	3	4	5	6	7	Average
Soft Curd					(No Fat)				
	1868	96.90	92.58	88.79	87.51	74.05	78.96	80.46	85.61
	1871	76.72	77.24	73.19	77.04	86.56	96.79	85.79	81.83
	1872	89.69	75.51	72.79	81.30	78.14	82.84	83.51	80.54
					(3% Fat)				
	1893	89.06	82.14	81.48	86.61	67.42	73.33	71.49	78.82
	1894	83.96	73.64	65.17	80.40	71.97	91.58	90.41	79.59
	1906	88.30	77.06	84.07	86.41	77.80	83.91	90.49	84.40
					(6% Fat)				
	1909	85.76	86.89	95.38	93.73	96.88	86.72	95.48	91.55
	1911	87.48	86.89	83.10	85.54	85.99	82.48	92.90	86.34
	1926	76.66	90.74	92.50	90.03	94.65	93.81	94.78	90.45
Hard Curd					(No Fat)				
	1915	98.29	95.93	95.59	98.09	96.55	91.35	98.91	97.24
	1919	89.05	89.43	95.66	93.85	94.98	86.34	92.53	91.69
	1920*	88.50	89.93	95.81	96.38	96.38	97.38	97.56	94.64
					(3% Fat)				
	1929	90.18	96.51	98.71	97.63	98.02	98.54	97.24	96.69
	1930*	98.36	95.70	97.37	92.41	92.38	95.46	97.58	95.61
	1931*	93.93	94.62	96.59	95.82	96.26	96.74	95.85	95.69
					(6% Fat)				
	1934	93.22	94.56	88.82	92.62	92.38	88.34	95.85	92.26
	1935*	94.43	97.01	95.73	93.06	95.52	96.31	89.39	94.49
	1936*	93.87	92.54	91.36	97.28	92.00	93.87	95.13	93.72

*Purchased from private breeders.

TABLE XVI.

Nitrogen Digestion Coefficients and Other Data on Nitrogen Intake and Outgo With Calves Fed Milk Varying in Fat Content and Curd Tension

Milk Fed	Calf Number	Weight*	Age*	Date Trial Started	Date Trial Was Completed	Intake: Milk	Intake: Nitrogen	Outgo: Feces	Outgo: Nitrogen	Nitrogen Difference	Coefficient of Digestibility
		lbs.	days			gms.	gms.	gms.	gms.	gms.	
Soft Curd						(No Fat)					
	1868	114	12	12- 9-39	12-16-39	24004	115.7	1036	14.9	100.8	87.1
	1871	92	12	12-12-39	12-19-39	18916	91.2	771	16.4	74.8	82.0
	1872	80	12	12-14-39	12-21-39	16860	81.2	606	15.6	65.6	80.8
						(3% Fat)					
	1893	85	12	2- 9-40	2-16-40	14105	68.0	3104	18.6	49.4	72.6
	1894	106	12	2-11-40	2-18-40	15323	73.8	1145	13.5	60.3	81.7
	1906	115	14	3-22-40	3-29-40	25264	121.8	1236	19.0	102.8	84.4
						(6% Fat)					
	1909	85	12	4- 2-40	4- 9-40	20451	98.6	543	8.1	90.5	91.8
	1911	88	15	4- 6-40	4-13-40	22071	106.4	606	14.5	91.9	86.4
	1926	99	12	6-16-40	6-23-40	22395	107.4	542	10.2	97.2	90.5
Hard Curd						(No Fat)					
	1915	98	12	4-27-40	5- 4-40	25515	174.3	207	4.7	169.6	97.3
	1919	92	12	4-28-40	5- 5-40	21066	143.9	710	12.2	131.7	91.5
	1920**	96	13	7- 3-40	7-10-40	28375	193.8	452	10.3	183.5	94.7
						(3% Fat)					
	1929	96	12	6-24-40	7- 1-40	23800	162.5	293	5.4	157.1	96.7
	1930**	115	12	6-25-40	7- 2-40	34300	234.2	499	10.3	223.9	95.6
	1931**	112	12	6-25-40	7- 2-40	34300	234.2	725	10.1	224.1	95.7
						(6% Fat)					
	1934	93	12	7-14-40	7-21-40	22473	153.4	663	11.8	141.6	92.3
	1935**	126	12	7-17-40	7-24-40	28375	193.4	544	10.6	183.2	94.5
	1936**	108	12	7-22-40	7-29-40	28602	195.3	669	12.3	183.0	93.7

*Weight and age at beginning of trial.
**Purchased from private breeders.

3. The Protein Digestion Trial.

In most of the reports on protein digestion the terms "apparent coefficients of nitrogen digestion" and "coefficients of protein digestion" were used interchangeably. This practice will be continued in this thesis.

In Table XV are presented the daily nitrogen digestion coefficients which are also summarized in Table XVI. These coefficients were obtained with 18 calves on seven-day digestion trials. The nitrogen digestion coefficients were determined in the following manner,

$$\text{coefficient of protein digestion} = \frac{\text{feed nitrogen} - \text{feces nitrogen}}{\text{feed nitrogen}} \times 100.$$

The averages of the protein digestion coefficients (Table XV) are presented in Table XVII.

TABLE XVII.

Means of Nitrogen Digestion Coefficients Obtained with 16 Calves Fed Soft and Hard Curd Milk with Zero, 3 and 6 Per Cent Fat

Milk	Fat			
	Zero	3%	6%	Average
Soft curd	82.7	84.4	89.4	85.5
Hard curd	94.5	96.0	93.5	94.7
	88.6	90.2	91.5	

The data (Table XV) were analyzed by analysis of variance to determine if the coefficients of digestion differed significantly when the calves were fed soft and hard curd milk containing zero, 3 and 6 per cent fat. The analysis is presented in Table XVIII.

TABLE XVIII.

Variance Analysis of Nitrogen Digestion Coefficients Obtained with Calves Fed Soft and Hard Curd Milk Containing Zero, 3 and 6 Per Cent Fat

Source of variation	Degrees of freedom	Mean square
Total	111	
Curd	1	2158**
Fat	2	186*
Curd x fat interaction	2	196.9*
Experimental error	10	33.4
Sampling error	96	19.2

* 5% level of significance
** 1% level of significance

The variance analysis shows that the curd tension of milk had a highly significant effect on the nitrogen digestion coefficients. The proteins of hard curd milk had significantly higher coefficients of digestion than the proteins of soft curd milk. The amount of fat in the milk has a significant effect

on the nitrogen digestion coefficients. The highest digestion coefficients (91.5) was obtained with calves on the 6 per cent fat level and it differed significantly (91.5-88.6=2.9)* from the lowest coefficient (88.9) obtained with calves on the fat free milk.

* $(t.05)\ (\bar{sd}) = 2.228\ \sqrt{2 \times 33.4/42} = 2.81$

TABLE XIX.

Titratable Acidity of Daily Fecal Excretions
In Cubic Centimeters of Normal
Potassium Hydroxide

Milk Fed	Calf Number	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total
		cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.
Soft Curd									
					(No Fat)				
	1868	40.2	39.4	89.1	22.6	76.1	40.7	18.7	326.8
	1871	38.9	87.3	76.8	150.8	117.0	23.9	87.5	582.2
	1872	93.6	87.5	98.0	37.4	29.3	36.6	37.0	419.4
					(3% Fat)				
	1893	93.8	96.7	45.3	96.3	69.5	32.7	71.7	501.0
	1894	98.7	88.4	48.1	96.6	16.1	48.8	74.5	466.2
	1906	94.9	43.7	56.1	43.9	50.8	34.2	80.5	404.1
					(6% Fat)				
	1909	20.6	22.1	80.6	89.2	99.5	66.4	72.6	461.0
	1911	83.6	85.9	50.1	33.7	89.7	54.8	31.7	427.5
	1926	38.3	18.8	85.8	55.6	69.7	96.5	76.8	440.5
Hard Curd									
					(No Fat)				
	1915	38.6	49.7	54.4	32.9	58.9	67.2	38.3	340.0
	1919	67.2	39.9	98.6	101.9	68.6	121.3	74.4	571.9
	1920*	33.4	21.0	79.1	49.7	68.5	78.8	83.3	383.7
					(3% Fat)				
	1929	30.6	77.3	42.1	70.4	53.8	45.6	84.1	403.9
	1930*	57.4	141.0	50.1	149.2	78.9	36.6	39.7	552.9
	1931*	95.2	99.1	59.9	67.3	90.7	49.7	33.3	495.2
					(6% Fat)				
	1934	17.6	15.4	29.9	36.6	22.7	103.9	121.5	347.6
	1935*	21.8	14.2	121.3	20.4	89.3	77.3	39.4	383.7
	1936*	39.9	47.9	87.3	113.0	67.6	38.7	99.3	493.7

*Purchased from private breeders.

4. Reaction of the feces.

a. Titratable acidity. The titratable acidity values which were taken daily are presented in Table XIX. The titratable acidity values are presented in terms of cubic centimeters of normal potassium hydroxide. The averages of the titratable acidity factors of the feces from calves when they were fed soft and hard curd milk containing zero, 3 and 6 per cent fat are presented in Table XX.

TABLE XX.

Averages of Titratable Acidity of Feces Collected for Seven Days from 16 Calves Fed Milk Varying in Fat Content and Curd Tension, in Cubic Centimeters of Normal Sodium Hydroxide

	Fat			
Milk	No fat cc.	3% cc.	6% cc.	Average
Soft curd	63.2	65.3	63.0	63.8
Hard curd	63.1	69.1	58.3	63.5
	63.2	67.2	60.6	

In order to discover if different diets affect the titratable acidity of the feces from calves, the titratable acidity values (Table XIX) were subjected to a statistical analysis. The results are presented in Table XXI.

TABLE XXI

Variance Analysis of Daily Fecal Titratable Acidity Factors Taken from Calves Fed Soft and Hard Curd Milk Containing Zero, 3 and 6 Per Cent Fat

Source of variation	Degrees of freedom	Mean square
Total	111	
Curd	1	2.9
Fat	2	462.0
Curd x fat interaction	2	188.2
Experimental error	12	1064.7
Sampling error	94	946.4

The variance analysis (Table XXI) shows that different milk diets when fed to calves did not cause any significant variations in the titratable acidity of their feces.

TABLE XXII.

Free Fatty Acids in Daily Fecal Excretions from Calves
In Cubic Centimeters of Normal
Potassium Hydroxide

Milk Fed	Calf Number	Days 1	2	3	4	5	6	7	Total
		cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.
Soft Curd									
					(No Fat)				
	1868	1.10	1.83	5.44	6.85	2.42	7.37	9.60	34.61
	1871	5.60	9.58	9.27	10.41	3.22	1.87	2.22	42.17
	1872	1.06	6.61	5.51	4.57	4.05	4.43	9.58	35.81
					(3% Fat)				
	1893	4.77	7.81	26.15	18.19	19.60	21.73	5.20	103.45
	1894	4.70	10.43	10.06	3.96	6.28	2.35	3.54	41.32
	1906	24.30	6.26	12.89	8.87	9.86	7.99	3.41	73.58
					(6% Fat)				
	1909	9.80	3.26	2.43	4.14	1.82	1.21	2.77	25.43
	1911	4.52	6.09	9.35	8.30	8.00	10.53	4.01	50.80
	1926	30.31	7.98	8.63	7.80	3.81	5.77	6.89	71.19
Hard Curd									
					(No Fat)				
	1915	.74	1.99	.84	.34	.96	.64	.96	6.47
	1919	4.74	5.08	1.83	1.80	1.69	7.67	5.71	28.52
	1920*	3.78	4.92	.98	5.75	3.81	1.33	2.78	23.35
					(3% Fat)				
	1929	14.91	3.59	1.00	1.47	2.86	.88	1.07	25.78
	1930*	.87	6.32	6.02	9.77	10.61	6.59	3.08	43.26
	1931*	9.75	6.41	5.78	6.24	4.44	3.54	3.92	40.08
					(6% Fat)				
	1934	13.60	7.02	12.17	7.57	13.67	20.93	5.31	80.27
	1935*	4.22	1.91	1.81	4.69	2.25	2.67	6.30	23.85
	1936*	15.36	5.92	2.48	6.55	6.26	5.38	1.96	43.91

*Purchased from private breeders.

b. Free fatty acids. The free fatty acid values other than those for the volatile fatty acids were determined on the daily feces of young calves fed soft and hard curd milk containing zero, 3 and 6 per cent fat. The free fatty acid values are presented in terms of cubic centimeters of normal potassium hydroxide. The results of these determinations are presented in Table XXII. The averages of the free fatty acid factors of the feces from calves when they were fed soft and hard curd milk containing zero, 3 and 6 per cent fat are presented in Table XXIII.

TABLE XXIII.

Averages of Free Fatty Acids of Feces Collected for Seven Days from 16 Calves Fed Milk Varying in Fat Content and Curd Tension, in Cubic Centimeters of Normal Sodium Hydroxide

	Fat			
Milk	No fat cc.	3% cc.	6% cc.	Average
Soft curd	5.36	10.40	7.02	7.59
Hard curd	2.78	5.20	6.62	4.87
	4.07	7.80	6.82	

In order to discover if different diets affect the free fatty acids of the feces from calves, the free fatty acid values of Table XXII were statistically analyzed. The results of this analysis are shown in Table XXIV.

TABLE XXIV.

Variance Analysis of Daily Free Fatty Acid Factors in Daily Fecal Secretions of Calves Fed Soft and Hard Curd Milk Containing Zero, 3 and 6 Per Cent Fat.

Source of variation	Degrees of freedom	Mean square
Total	111	
Curd	1	235.1
Fat	2	157.2
Curd x fat interaction	2	60.4
Experimental error	10	62.4
Sampling error	96	20.2

This analysis shows that when milk with varying fat level and curd tension is fed to calves, the free fatty acid content of the feces is not significantly affected.

TABLE XXV.

Fatty Acids Present As Soap in Daily Fecal Excretions
In Cubic Centimeters of Normal
Potassium Hydroxide

Milk Fed	Calf Number	Days 1	2	3	4	5	6	7	Total
		cc.	cc.	cc.	cc.	cc.	cc.	cc.	cc.
Soft Curd									
					(No Fat)				
	1868	1.59	6.45	8.88	6.06	4.13	5.14	5.99	38.24
	1871	4.88	3.08	4.30	5.85	1.36	1.53	2.82	23.82
	1872	2.99	7.92	5.13	6.27	3.02	2.85	4.02	32.20
					(3% Fat)				
	1893	4.08	6.12	8.18	4.33	7.49	5.41	5.72	41.33
	1894	4.19	3.58	3.77	3.26	2.87	4.34	7.48	29.49
	1906	7.17	6.49	2.75	3.90	5.72	5.55	4.06	35.64
					(6% Fat)				
	1909	4.22	7.85	4.35	3.32	2.35	6.49	2.09	30.67
	1911	1.88	2.89	6.19	8.74	4.19	5.08	2.69	31.66
	1926	2.68	2.52	4.61	7.31	3.32	1.25	1.36	23.05
Hard Curd									
					(No Fat)				
	1915	1.34	5.87	3.29	1.64	3.22	1.14	1.29	17.79
	1919	6.87	6.88	1.91	4.99	2.66	6.79	6.88	36.98
	1920*	4.22	9.19	2.78	1.61	1.68	7.59	3.00	30.07
					(3% Fat)				
	1929	6.03	2.31	.48	2.30	.91	1.44	1.61	15.08
	1930*	2.83	6.67	2.23	6.60	6.70	2.65	3.60	31.28
	1931*	5.73	6.99	6.13	3.40	1.71	3.12	9.96	37.04
					(6% Fat)				
	1934	3.44	2.37	1.45	5.79	3.91	7.23	3.47	26.66
	1935*	2.06	1.62	2.95	3.11	1.22	1.74	9.68	22.39
	1936*	2.01	8.00	8.02	1.69	3.88	5.90	2.90	32.40

*Purchased from private breeders.

c. Fatty acids as soap. The daily fatty acids present as soap were determined from the feces of calves fed soft and hard curd milk containing zero, 3 and 6 per cent fat. The results of these determinations are presented in Table XXV. The fatty acids present as soap are presented in terms of cubic centimeters of normal potassium hydroxide. Throughout the results and discussion we shall use fatty acids interchangeably with fatty acids as soap. The averages of the free fatty acids of the feces from calves when they were fed soft and hard curd milk containing zero, 3 and 6 per cent fat are shown in Table XXVI.

TABLE XXVI.

Daily Average Amounts of Fatty Acids Present as Soap in Feces Collected for Seven Days on 16 Calves Fed Milk Varying in Fat Content and Curd Tension, in Cubic Centimeters of Normal Potassium Hydroxide

	Fat			
Milk	No fat cc.	3% cc.	6% cc.	Average
Soft curd	4.49	5.07	4.06	4.54
Hard curd	4.04	3.97	3.92	3.98
	4.26	4.52	4.00	

The fatty acids of Table XXV were statistically analyzed to determine if the fatty acid content of the feces is affected by varying the curd tension and fat level of

milk fed to calves. The results of this analysis are shown in Table XXVII.

TABLE XXVII.

Variance Analysis of Fatty Acids Present as Soap in Daily Fecal Excretions of 16 Calves Fed Milk with Varying Fat Content and Curd Tension

Source of variation	Degrees of freedom	Mean square
Total	111	
Curd	1	9.9
Fat	2	2.9
Curd x fat interaction	2	2.5
Experimental error	10	8.5
Sampling error	96	4.7

The results of this analysis show that the fatty acids in the feces of calves are independent of varying curd tension and fat level in the milk used.

D. Discussion

1. The skim milk experiment.

The daily amounts of fat in the feces of calves fed soft and hard curd skim milk are presented in Table VIII and summarized in Table IX. The variance analysis (Table X) of these data (Table VIII) shows that fat-free milk characterized by soft and hard curd when fed to calves causes no significant differences in the amounts of fat in the feces.

The average daily amounts of feces fat (Table IX) were 1.18 and .59 grams respectively when soft and hard curd skim milk were fed to calves. Since the amounts of feces fat are not influenced by the curd character of fat-free milk then the average of the means, .9 gram, is the logical factor to use in correcting for endogenous fat metabolism in the fat digestion trials.

The presence of ether extract in the feces of animals on fat free diets has been found by other workers (36,55,64) in varying quantities. Cannon, Espe, and Waide (10) found a daily fat excretion of 2.3 grams, while Prytz (55) found 1.27 grams of fat in the feces of calves fed fat-free milk. The ether extract in the feces of animals on a fat-free diet probably originates from intestional bacteria desquamated intenstinal

cells or excretions from the blood (65).

The range of the daily amounts of fat in the feces of calves on fat-free milk diets was from .16 to 2.23 (Table VIII).

2. The fat digestion trial.

In our trials the average coefficient of fat digestion was 97.56 while the range of the coefficients was from 92.48 to 99.69 (Table XI). Other workers have obtained equally as high coefficients of fat digestion (10,12,36, 37).

The variance analysis (Table XIV) shows that when soft or hard curd milk containing 3 or 6 per cent fat was fed to calves the efficiency of fat digestion was not significantly affected. The average coefficients of fat digestion were 97.18 and 97.94 respectively when soft curd milk containing 3 and 6 per cent fat and hard curd milk containing 3 and 6 per cent fat were fed to calves. Prytz (55) obtained the following fat digestion coefficients 95.63 and 95.43 respectively for soft and hard curd milk containing an average of 4 per cent fat.

The digestibility of fat was equally as high on the 3 per cent as on the 6 per cent fat level, with respective coefficients of 97.36 and 97.77. The coefficients obtained by Prytz (55) were 94.17 and 96.89 respectively when milks containing 2 and 6 per cent fat were fed to calves.

Evidence has been presented to show that the efficiency of fat digestion in young calves is not affected by the feeding of soft or hard curd milk containing 3 or 6 per cent fat.

In the light of these findings, then, calves will digest butterfat as well when they are fed soft or hard curd milk containing 3 or 6 per cent fat.

Calves 1893 and 1894 on the soft curd milk containing 3 per cent fat scoured intermittently. In metabolism trials at this station with young calves, Mann (51) observed that both the percentage of fat in the feces and the total amount excreted were greater during periods of scouring. For this reason the data from calves 1893 and 1894 were not used in the analyses.

3. The protein digestion trial.

Digestion coefficients of 85.5 and 94.7 respectively for the proteins were obtained when soft and hard curd milk were fed to young calves. The variance analysis (Table XVIII) of the data indicates a highly significant difference between the nitrogen digestion coefficients 85.5 and 94.7 respectively when soft and hard curd milk were fed to young calves. Other investigators (14, 55, 40) have obtained results indicating that hard curd milk has higher coefficients of protein digestion than soft curd milk.

Because hard curd milk remains in the stomach longer (19, 37, 49) and has a higher coefficient of protein digestion than soft curd milk it is evidence that protein digestion may be associated with length of time the milk coagulum remains in the stomach. This is further supported by the work of Doan and Welch (16) who fed calves and rats soft and hard curd milk and when post-mortem examinations were made the soft curd was found mainly in the large intestine while the hard curd was in the lower end of the small intestine.

The coefficients of nitrogen digestion obtained when calves were fed hard curd milk with zero, 3 and 6 per cent fat respectively were 94.5, 96.0 and 93.5. No significant differences were found between these means indicating that fat on the levels used had no measurable influence on the digestion of the protein that was in the hard curd milk. On the other hand the addition of fat to the soft curd milk at the same levels that were used in the hard curd milk caused significant increases in the retention of the nitrogen of the soft curd milk. The protein digestion coefficients 82.7, 84.4 and 89.4 respectively were obtained when soft curd milk containing zero, 3 and 6 per cent fat was fed to calves.

These differences in the digestibility of the proteins of hard and soft curds caused by fat are rather difficult to understand. Some investigators (11,39,56,58) claim that fat interferes with gastric digestion while others (14,19) claim that fat in milk speeds up the liquefaction of milk in the stomach and its disappearance therefrom, which is an indication of more speedy digestion. If time is an element of the more complete digestion of hard curd, as has been proposed, then because fat increases the rate of disappearance of milk curd from the calf's stomach it should also cause the curd to be less thoroughly digested. Our results did not sustain this later conclusion.

Certainly our results, and they were sustained by Prytz (55), Dickey (14), Magee and Harvey (40), prove that the protein of hard curd is more completely digested than that of soft curd. As with many chemical processes, and digestion is a chemical process, the more nearly the reaction approaches the 100 per cent level the more difficulty disturbing agencies have in affecting it.

In this case fat is the disturbing agent, causing a more complete digestion of the curd into which it is incorporated probably through causing a greater surface exposure of the curd to attack by the gastric enzymes. Consequently the effect of fat in increasing protein digestion is measurable when the coefficient is relatively low, as with soft curd, while the improvement in digestibility of the protein of the hard curd with its high coefficient of digestion through the presence of fats is not measurable, though one can guess that if the techniques of analysis were sensitive enough some improvement could be found. The law of diminishing returns is noticeable in the effectiveness of the presence of fat on curd digestibility.

In summarizing our data in the light of that gathered by other workers it can be said that even though when fat is added to a general diet it delays the emptying time of the stomach, fat added to milk has an opposite effect of speeding up the

gastric liquefaction and disappearance of milk curd. This increased rate of digestion of the milk curd brought about by the incorporation of fat is reflected in a higher coefficient of digestion because the fat causes extra surface to be exposed to the gastric enzymes thus leaving fewer and smaller undigested particles of curd to pass from the stomach into the small intestine.

Apart from the effect of fat the low coefficient of digestion of the soft curd protein indicates that more undigested particles are escaping into the intestinal area than is true with hard curds even though the speed of digestion is more rapid in soft curds due to the greater surface area exposed to digestive action. By their very nature soft curds are made up of small loosely held together pieces while hard curds are more solid with relatively few and tightly held together pieces. The digestive juices attack the surface of each of these pieces digesting from the mass constantly until the mass becomes so small that it can float in the gastric juices and be ejected from the stomach through the pyloric valve. The many pieces in the soft curd offer a large surface area for rapid digestion but it also produces as digestion proceeds many undigested pieces, small enough to pass through the pylorus. The large tough pieces of the hard curd offer less surface for digestive action and in the end fewer pieces of undigested material small

enough to pass from the stomach than soft curds. The difference in digestion coefficients between these two kinds of curd are explainable through the difference in quantity of undigested portions passing from the stomach. In this view there is no disagreement between greater speed of digestion found with soft curd milk and the higher coefficient of digestion found with hard curd milk.

The results of our metabolism work show that the coefficients of nitrogen digestion were increased when 3 and 6 per cent fat were added to soft curd milk, while no increase in nitrogen retention was observed when 3 or 6 per cent fat was added to hard curd milk. Strictly from a nutritional point of view, then, the addition of 3 or 6 per cent fat to low curd milk (Holstein and Ayrshire) would increase the nitrogen retention of that milk when fed to calves.

4. Reaction of the feces.

a. Titratable acidity. In Table XIX are presented the daily titratable acidity factors determined from the feces of calves fed soft and hard curd milk containing zero, 3 and 6 per cent fat. The variance analysis shows that the different diets as used in this experiment have no significant effect on the titratable acidity of the feces.

The curd tension of milk had no significant effect on the titratable acidity of the feces. The average titratable acidity factors of the feces were 63.8 and 63.5 respectively when soft and hard curd milks were fed to calves. The addition of fat to fat-free milk and then feeding it to calves had no significant effect on the titratable acidity of the feces. The average titratable acidity factors were 63.2, 67.2 and 60.6 respectively for the milk containing zero, 3 and 6 per cent fat. These results are substantiated by Grazel and Miller (23) and Howe and Hawk (33) whose work indicates that variations in diet are not accompanied by consistent fluctuations in the fecal reaction.

The range of the daily titratable acidity factors was from 15.4 to 150.8 (Table XIX). The variance analysis (Table XXI) has accounted for the variation in the titratable acidity factors that was caused by varying the curd tension and fat content of milk. The large mean square for experimental error

(Table XXI) indicates that factors, independent of the curd and fat variables, were affecting the titratable acidity of the feces and probably causing it to fluctuate.

The digestion coefficients of fat and nitrogen show no relationship to the titratable acidity in the feces of calves. This relationship and those following were determined by inspection of the trends of the respective means under consideration.

b. Free fatty acids. In Table XXII are presented the daily fatty acid factors determined from the feces of calves fed soft and hard curd milk containing zero, 3 and 6 per cent fat. The variance analysis of these data is shown in Table XXIV. This analysis (Table XXIV) shows that the different diets as used in this experiment have no significant effect on the free fatty acid content of the feces.

The curd tension of milk had no significant effect on the free fatty acid content of the feces. The average free fatty acid measurements of the feces were 7.59 and 4.87 respectively when soft and hard curd milks were fed to calves. The addition of fat to fat-free milk and then feeding it to calves had no significant effect on the free fatty acid content of the feces. The average free fatty acid factors were 4.07, 7.80 and 6.82 respectively for the milk containing zero, 3 and 6 per cent fat. The mean differences between the free fatty acids associated with the different fat levels and curd tensions are ascribed to errors of random sampling from a homogeneous population. The mean differences are large because the means themselves were taken from a varying population.

The range of the daily free fatty acid measurements was from .96 to 24.30 (Table XXII). Most of the variation in the data presented in Table XXII was accounted for by the varying curd and fat content of the diets.

The results of our trials show that the free fatty acids are not correlated with fat or nitrogen digestion.

c. Fatty acids as soap. In Table XXV are presented the daily amounts of fatty acids as soap determined from the feces of calves fed soft and hard curd milk containing zero, 3 and 6 per cent fat. The variance analysis of these data are presented in Table XXVII and shows that the different diets used in this experiment have no significant effect on the fatty acids as soap in the feces.

When soft and hard curd milks were fed to calves no significant difference was found between the means of the fatty acid content of the feces. The average daily amounts of fatty acids in the feces were 4.54 and 3.98 respectively when soft and hard curd milks were fed to calves. The addition of fat to fat-free milk and feeding it to calves had no significant effect on the fatty acid content of the feces.

The average daily amount of fatty acids were 4.26, 4.52, and 4.00 respectively for the milk containing zero, 3 and 6 per cent fat. The fatty acid content of the feces is not significantly affected when soft and hard curd milks containing zero, 3 and 6 per cent fat are fed to calves. Howe (32) states that when there is a high fat content in the feces

there is present a greater proportion of fatty acids in the form of soaps and give an indication of the absorption or lack of absorption of fat from the intestine. In our work the fat was not sufficiently high to cause a decreased fat absorption, and consequently no change in the fatty acid content of the feces was observed.

The range was from .48 to 9.69 (Table XXV). In contrast with the titratable acidity and free fatty acid content of feces the fatty acids as soap do not show as large daily fluctuations.

In these trials the fat and nitrogen digestion coefficients give no indication of a relationship with the fatty acids as soap content of the feces.

E. Conclusions

The results of the metabolism trials in which 16 calves were used, support the following general conclusions:

1. Variations in the curd tension of skim milk fed to young calves failed to change significantly the quantity of fat in their feces.
2. Efficiency of fat digestion in young calves is not significantly affected by the feeding of soft or hard curd milk containing 3 or 6 per cent fat.
3. Protein digestion with calves was significantly increased by the toughness of the milk curd for the proteins of hard curd milk have significantly higher digestion coefficients than the proteins of soft curd milk. Protein digestion coefficients of hard curd milk did not change with changes in fat content while increases in the fat content of soft curd milk caused increases in the coefficients of digestion of the protein in this milk.
4. Varying fat content and curd character of milk fed to calves did not affect the titratable acidity, free fatty acid, and fatty acids as soap content of the feces.

5. The fat and protein digestion coefficients were not correlated with the titratable acidity, free fatty acid of fatty acids, as soap content of the feces.

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ACKNOWLEDGMENT

The writer wishes to express his sincere appreciation to all of those who have contributed, in any way, to this thesis. He wishes, especially, to acknowledge his indebtedness to Dr. Clausen Y. Cannon for his counsel throughout the course of the investigation and for his constructive criticisms and suggestions in the preparation of the manuscript; to Professor Victor E. Nelson for his aid in the laboratory and also to Dr. Dwight L. Espe for his constructive criticisms of this thesis.